Some Results on Parallel Acquisition in CDMA Systems

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Abstract — When the receiver in a direct-sequence code-division multiple-access (CDMA) system attempts to synchronize to (i.e. acquire) a desired received signal, it must contend with the interference from the other transmitters in the same frequency band. This paper presents some strategies for acquisition that use parallel observations, and provide some relief from the near/far problem in CDMA communication systems.

When a receiver in a direct-sequence code-division multiple-access (CDMA) communication system attempts to acquire a particular transmitter's signal, it must contend with the interference due to the signals from the other transmitters. We assume that the receiver knows all the signature sequences in use, and can simultaneously (that is, in parallel) correlate the received signal with all the different cyclic shifts of the various signature sequences, and study how the receiver must process these observations to estimate the relative delays of the various signals.

In a CDMA system, the interference in the correlators from the signals from the other transmitters is a function of the crosscorrelation of the signature sequences. In theory, such interference can be reduced by choosing sequences with low crosscorrelation. However, in practice, the various signals can be received with very widely differing signal powers, and the relative strength of the signal from a powerful transmitter can cause severe problems in acquiring or demodulating a weak signal. This is the so-called near/far problem that has been the subject of much study in recent years, primarily in the context of demodulation. In many practical systems, stringent power control is used to equalize the received power of each signal. The near/far problem also affects the acquisition system, and our studies include the effects of varying signal levels on the performance of the various acquisition strategies. Curiously, our schemes perform the worst when the signal powers are nearly equal and perform very well when signal powers are widely different, which suggests that perhaps power control is best applied after the signals have been acquired.

In a parallel acquisition scheme, the receiver correlates (in parallel) the received signal with all possible phases of the spreading sequence and then attempts to estimate the relative time delay of the received signal from these observations. We first consider the somewhat impractical case of a system that is chip-synchronous, that is, the chips (or bits) in the various signature sequences start and end at the same time. The most straightforward strategy in this case is to correlate

the received signal against all the cyclic shifts of all signature sequences and then use ordinary M-ary detection techniques to acquire all the signals simultaneously. This method ignores the interference effects. Unfortunately, not only is the method quite expensive to implement because of the large number of correlators, but it suffers severely from the the near/far problem. It is far better to use the data to decide which signal is the strongest and acquire that signal first. Next, the received signal is projected orthogonal to the first signal, and the projection is correlated with the cyclic shifts of the remaining (non-acquired) sequences. Once again, the strongest remaining signal is chosen and acquired, and the received signal is projected orthogonally, etc. One other scheme is to compute the projection of the received signal orthogonal to all possible shifts of the signature sequences. The projection with the smallest norm is then taken to correspond to the correct delays. This scheme also requires substantial amounts of computation. Unfortunately, it does not perform as well as the decorrelating strategy discussed above.

The strategies for the more practical chip-*asynchronous* CDMA systems are similar to those described above. We have studied estimation schemes for the delay in single-user chip-asynchronous systems [1] and we use the simplest of these in the multi-user strategies needed for CDMA systems. The decorrelation scheme discussed above does not work as well as might be expected, in part because the estimates of the delays of the stronger signals are not perfect. Hence, the interference from the stronger signals is not perfectly eliminated when acquiring weaker signals. However, since the delays are estimated fairly accurately to within a chip duration (say between k and $k+1$ chips), it is possible to decorrelate against the subspace spanned by the k-th and $(k+1)$-th cyclic shifts of the signature sequence and thereby improve performance.

Numerical results on the performance of these strategies for parallel acquisition are not included here for lack of space but will be presented orally. We will compare how successful the schemes are in ameliorating the effects of the near/far problem. We will also present some simple analytical approximations to the performance of some of these schemes. Detailed descriptions of all of these can be found in [2].

REFERENCES

[1] M. Srinivasan and D. V. Sarwate, "Simple schemes for parallel acquisition of spreading sequences in DS/SS systems," *IEEE Transactions on Vehicular Technology,* August 1996.

[2] M. Srinivasan, "Parallel acquisition of spreading sequences in direct-sequence spread-spectrum communication systems," Ph.D. thesis, Department of Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, Urbana, Illinois 61801 USA, October 1996.